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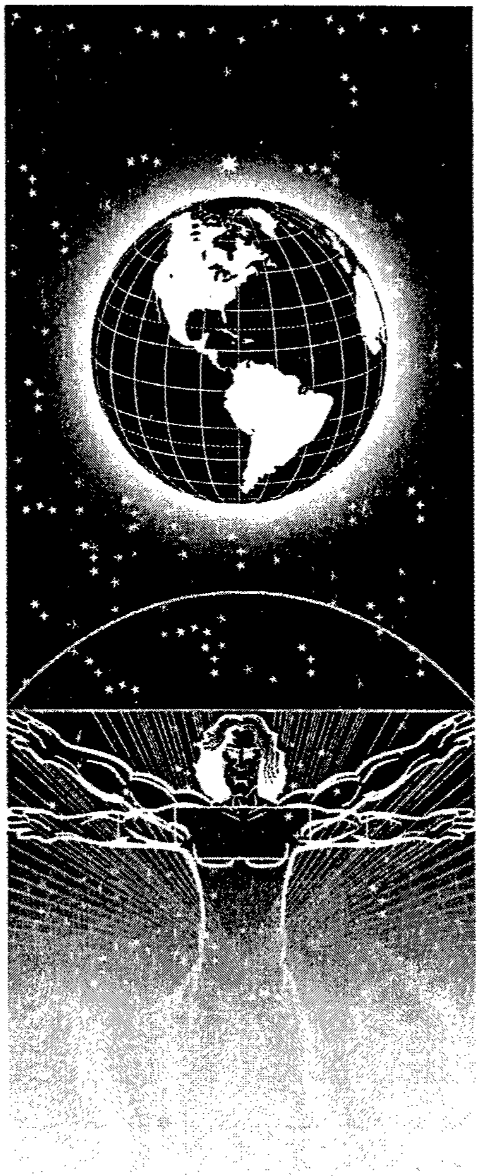

UNITED STATES AIR FORCE RESEARCH LABORATORY

TASER AREA DENIAL DEVICE: A HUMAN EFFECTS REVIEW

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The Taser Area Denial Device (TADD) is a non-lethal alternative to anti-personnel landmines and is a concept based on Taser technology. Specifically, the TADD is based on electronic components manufactured and sold by TASERTRON, who exclusively manufactures Taser products for law enforcement agencies. The concept is not commercially available and is early in its developmental stage. The TADD should incapacitate an individual without causing any acute or long term injury. With the exception of the independent studies mentioned in this report, the electrical effects on humans are extracted from experiments and case reports dealing with post exposure clinical evaluations or anecdotal reports from the manufactures or users. These anecdotal reports are essentially endorsements and should be viewed with the same critical eye as any endorsement.

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FIGURE

1.0 Introduction

The Taser Area Denial Device (TADD) is a non-lethal alternative to anti-personnel landmines and is a concept based on Taser technology. Specifically, the TADD is based on electronic components manufactured and sold by TASERTRON, who exclusively manufactures Taser products for law enforcement agencies. This concept is not commercially available and is early in its developmental stage. The TADD should incapacitate an individual without causing any acute or long-term injury. With the exception of the independent studies mentioned in this report, the electrical effects on humans are extracted from experiments and case reports dealing with post exposure clinical evaluations or anecdotal reports from the manufacturers or users. These anecdotal reports are essentially endorsements and should be viewed with the same critical eye as any endorsement.

1.1 The Taser

Several hundred law enforcement agencies use various versions of the Taser (Thomas A Swift's Electric Rifle)-like devices or "stun guns" as a non-lethal alternative. The Taser is a hand-held, electronic defense and immobilization weapon that has been commercially available since 1974. Although painful, Taser devices do not rely on pain for compliance.

Several Taser models are marketed for public use or for use by law enforcement agencies. One of the main differences between the models is that the power output of the law enforcement model is twice that of the public model. The two largest companies that manufacture and distribute Taser weapons are TASERTRON and TASER International. The TADD is based on technology manufactured and sold by TASERTRON. The TASERTRON product weighs about 1.5 lbs. and consists of a nickel-cadmium power source, electronic circuitry, and one or two (depending on the model) dart cartridges containing two darts each. Each dart weighs 1.4g and is connected to the Taser by a 15ft. (4.6m) wire. When the trigger on the Taser is pressed, a gunpowder charge explodes, firing the two darts from the cartridge at a velocity of 55m/sec (180ft/sec); at 4 meters, the velocity is 30m/sec (98ft/sec). When both darts penetrate the victim's skin or clothing, a high voltage (50,000 volts, 8-10mA, and 5 watts) electrical pulse train of 8-13 pulses/sec is transmitted to the victim through the wires. (Alternatively, two antennae located at the end of the device can be used to deliver the same pulse train when touched to the victim's skin.) The pulse train is transmitted as long as the trigger is depressed for a maximum of about 108 seconds, the duration of battery life. Most Taser victims fall to the ground and experience rhythmic, involuntary muscular contractions as long as the current is delivered. (Koscove, 1985)

When fired, the top dart in the TASERTRON's cartridge is designed to travel in a straight line, while the bottom dart travels downward at a 12° angle. There is a 12-inch dart separation at 5 feet, 24-inch separation at 10 feet, and a

36-inch separation at 15 feet. Currently, the maximum range of the TASERTRON cartridges is 15 feet from the end of the gun. (Laur, 1999) TASERTRON is considering the development of a cartridge with a 30-foot range that can be used interchangeably in all present TASERTRON products. (McNulty, 1995)

The darts only penetrate ¼in. (6.4mm), but an electrical arc or spark of 1.25in. (32mm) is produced at the end of the dart. Therefore, the dart does not have to be embedded in the skin for the weapon to be effective; the current will easily pass through clothing. As long as both darts are embedded in the skin or clothing, the weapon should be effective. (Kornblum, 1991)

1.2 The TADD

In contrast to the conventional TASERTRON or TASER International devices, the TADD is designed to be a military weapon and thus would have more stringent operational parameters and concepts of employment. The TADD is based on electronic components manufactured by TASERTRON. Conceptually, the TADD, when triggered by sensors, will launch darts horizontally at 10-20 degree intervals for a distance of 15 feet (potentially 30 feet). The TADD will fire up to 20 sets of darts and would be deployed along defensive line perimeters or anti-tank mine fields. The TADD will incapacitate the forward line of troops and any troops that touch the incapacitated target while the current is being applied. Also, both darts do not have to contact the target for the Taser effect to occur. One dart can hit the target while the other hits the ground or one dart can hit the target while the other dart hits another target and both targets contact each other. As long as there is a pathway for conduction, the electrical circuit will be completed. Unlike the handheld Taser type devices, there is no man in the loop, thus, the target will continue to be incapacitated as long as power is applied, i.e. as long as the battery lasts. The TADD can be deactivated remotely. At the time of this writing, it is proposed that incapacitation may last for a minimum of 10 minutes, with 1 second breaks every 10 seconds, which is the postulated amount of time necessary to allow the target to breathe normally.

2.0 Mechanism Of Interaction

The TASERTRON handheld Taser produces a peak voltage of up to 50,000-volts when discharged. At this voltage, approximately 0.8 joules of energy is delivered (Fish, 1993). However, TASERTRON reports a slightly lower output of 0.6 joules at the same voltage. The impedance of the human body determines the amount of current flow. The effect of these currents on the victim depends on the resistance of the skin, which depends in turn on pressure of contact, whether the skin is intact, and if it is wet. It appears that the electrical impulse is not just localized between the electrodes, but spreads from the point of contact along channels of low resistance throughout the body. Thus, a discharge of less than a second will repel the victim, but a discharge of 1-2 seconds will cause tetany of most of the striated (skeletal) muscle and the victim will fall. A discharge of 3-5 seconds will leave the victim unable to function for up to 15 minutes. Stiffness and pain in the muscles at the site are common after paralysis has worn off. (Robinson, 1990)

3.0 Effectiveness Data

3.1 Let-Go Current

The effect of electrical current on humans can be divided into three levels: the lowest level is called the "threshold of perception"; the next level is called the "let-go" current and is defined as the maximum level of electrical current that an individual can tolerate and still be able to let go of the electrical source; the highest level is the lethal current level. "At the lowest level, an individual might feel a slight tingle, but should have no startle reaction, pain, or other ill effects." (Kornblum, 1991) The average threshold for perception of current from a 60 Hz source is 0.36 and 0.24mA, for males and females, respectively (Bernstein, 1991). Let-go currents have been determined to be a minimum of 9mA for men at 60Hz. "Currents in excess of one's let-go level are said to "freeze" or "lock on" the victim to the circuit. Such currents are very painful, frightening, and hard to endure. Volunteers report that the current is so painful and causes such severe muscular contractions that it is incapacitating. The legs of the volunteers buckle and they fall to the ground." (Kornblum, 1991) "Let-go" current by percentile rank for males and females is shown in Figure 3.1 (Dalziel, 1972). "The lethal current level is the amount of current necessary to cause ventricular fibrillation, which is the most common mechanism of death associated with electrocution.

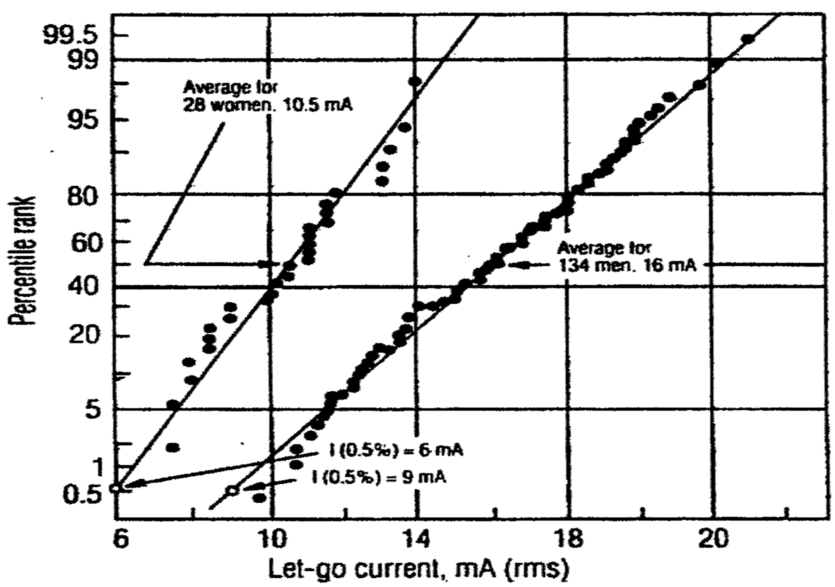

Figure 3.1. Let-go current by percentile rank for male and females. (Dalziel, 1972 *Reprinted with Permission*)

The amount of current necessary to cause ventricular fibrillation varies depending upon the duration, frequency, and the magnitude of the current. It also depends upon the body weight. The threshold for ventricular fibrillation has been determined to be approximately 150mA for 1 second at 60Hz. For shocks applied for more than 2 seconds, the level is believed to be 50mA." (Kornblum, 1991)

3.2 Effectiveness of the Taser

Kornblum and Reddy (1991) report that the handheld Taser was effective about 80% of the time when the Los Angeles Police Department (LAPD) used it. While most Taser victims are indeed incapacitated, it is not uncommon for a well motivated, highly focused subject to "fight" through the electrical experience. As a result, the two major Taser manufacturers mentioned in this report have developed a stronger product. This "new" Taser is capable of delivering about 1.5 joules, 25 watts of power, and up to 162mA while maintaining the original 50,000-volt electrical pulse. (Recall: the original TASERTRON products produced near 0.6 joules, 8-10mA, and 5 watts of power.) TASER International claims that it has "close to a 100% knockdown success rate" with the Advanced Taser. Both manufacturers claim that their products are both safe and effective.

4.0 Hazards to the body

Since the TADD is designed to deliver an electric current that produces involuntary muscle spasms and subsequent incapacitation to the target, the characteristics of the device must be assessed and compared with accepted electrical standards of safety. Since it's introduction, the Taser, has undergone exhaustive safety tests.

4.1 Lethality

They report the results of the autopsy of 16 males, 20 to 40 years of age, whose deaths were associated with the Taser in Los Angeles County between 1983 and 1987. Drugs, cocaine, PCP, or amphetamine were found in all but 3 cases. Taser wounds were found on each body. The Taser dart wound consists of a superficial punctate penetration of the skin, which was commonly surrounded by erythema. The penetration was generally less than 6.4mm and was usually surrounded by a thin zone of homogeneously coagulated tissue. Kornblum and Reddy concluded that the Taser caused none of the deaths.

4.2 Electrical Current and Ventricular Fibrillation

High voltage, per se, is not dangerous. One can receive a 25,000-volt shock from a doorknob on a dry day without harm. The physiological effect of electric shocks is determined by the amount of current and its duration. It is the power source behind the shock that determines these factors. The typical household current of a 110 or 120-volt source is dangerous because it can impart many amperes of current to the body indefinitely. By contrast, the Taser power supply consists of a small battery and is only capable of supplying a few watts of power for a few minutes. (McNulty, 1995)

However, one serious effect that can be produced by large currents is an effect on the heart known as ventricular fibrillation. Ventricular fibrillation is the most serious type of cardiac arrhythmia, in which the normal rhythm becomes disrupted because the cardiac muscle fibers are stimulating one another at such a rapid rate. Ventricular contractions are rapid, uncontrolled, and uncoordinated and the ventricles are incapable of pumping blood. Once the human heart goes into fibrillation it rarely recovers spontaneously.

Since experiments involving currents likely to produce fibrillation cannot be made on humans, the only recourse is to extrapolate animal data to man. Animal fibrillating current studies have been conducted on calves, pigs, dogs and sheep because these animals are comparable to humans in both heart and body weight (Dalziel 1972). These studies have shown that inducing ventricular fibrillation with a 50 to 60Hz current is a function of body weight, current magnitude, and shock duration. (O'Brien, 1991) For shocks less than 0.2 seconds in duration, the current to cause ventricular fibrillation is more than 500mA and would probably need to occur during the "T"-wave portion of the cardiac cycle (Robinson, 1990). For shocks longer than 2 seconds, the threshold is 50mA (Bernstein, 1991). Currents higher than 18mA may cause contraction of the chest muscles and prevents normal breathing (O'Brien, 1991). The 'asphyxia threshold' for 60 Hz current in animals is about 40mA. The TASERTRON products, however, produce 8-10mA, which is below the threshold levels that cause ventricular fibrillation.

In an independent study, Roy and Podgorski conducted a series of animal studies that showed the pigs response to an electrical stimulus. The stun guns used in their laboratory experiments were quite effective in producing asystole when discharged through 3 layers of Operating Room towels. Pump failure persisted as long as the gun was on and normal rhythm resumed as soon as the gun was turned off. Pump failure deteriorated into ventricular fibrillation if allowed to persist long enough (30 seconds or more). Experiments conducted directly on the pericardium of the exposed heart showed cardiac arrhythmias and ventricular fibrillation. In cases where a pacemaker was implanted, the pacemaker leads acted as a secondary winding of a transformer and provided an excellent pathway for the fibrillatory current. The heart went into immediate fibrillation as soon as the current was applied to the chest of the animal. (Roy and Podgorski, 1991)The stun guns used in the above experiments had an output of 0.00038-0.19mA, which is considerably lower than TASERTRON's output of 8-10mA. However, these stun guns produced an output up to 100,000 volts. This difference is at least twice the output of TASERTRON's 50,000 volts. Stratbucker and Marsh were unable to produce ventricular fibrillation in their study. They claim that the difference (between their study and Roy and

Podgorski's study) "may lie in the dissimilar current density patterns associated with differing application techniques." According to Stratbucker and Marsh, "no one has ever demonstrated an arrhythmic effect of [Less Than Lethal Weapons] when applied anywhere on the exterior of the body, human or otherwise." (Stratbucker and Marsh, electronic document)

However, according to another independent study, "the electrical output of the Taser ranges from 3mA to 10.9mA. These levels are well below the amount needed to cause ventricular fibrillation", when compared to the levels proposed by the U.S. Consumer Product Safety Commission ("an alternating current of 60 to 120mA at 120V and 60Hz is necessary to cause ventricular fibrillation). Therefore, there is a wide range of safety between the Taser output and level of current necessary to cause ventricular fibrillation." (Kornblum, 1991) The electrical output levels mentioned in this study, however, were not tested on animals. Rather, it is merely a comparison of output levels vs. proposed threshold levels.

The mortality rate associated with the use of the Taser is 1.4%. However, all fatalities were associated with PCP ingestion. There was one Taser-associated death without drug ingestion in an individual who apparently had a history of cardiac complications. (Ordog, 1987)

The power level of the Taser is far below the power necessary to cause heart fibrillation, in the worst-case scenario. The Taser has been shown in laboratory tests that it will not damage or interfere with operation of a pacemaker. Modern pacemakers are designed to withstand electrical defibrillator pulses, which are about 1,000 times stronger than the Taser output. (McNulty, 1995)

4.3 Non-electrical Injuries

One possible injury to a Taser victim is that of a fall from a standing position. Potential injuries include contusions, lacerations, fractures, and possibly intracranial hemorrhage or injury to the cervical spine. Another possible injury is that of dart penetration of the eye with subsequent rupture of the globe. Whether total loss of vision (from globe rupture or from transmission of electrical current through the eye) would result is unknown. (Koscove, 1985)

5.0 Conclusions

There are two main differences between the TADD and the conventional Taser. First, the TADD will have no man in the loop: that is, the device will continue to shock the subject as long as the battery lasts. Second, the conventional Taser is not grounded, except possibly through the body of the subject and/or the user. Because of the nature of the Taser experience, it would be difficult to do blinded experiments with humans, but it would be possible to do them with animals, because the animal has no pre-conceived notion of Taser effects.

Since the TADD is only a concept and based on Taser technology, the electrical effects on humans are extracted from Taser and/or stun gun experiments. With the exception of the independent studies mentioned in this report, the electrical effects on humans are extracted from experiments and case reports dealing with post exposure clinical evaluations or anecdotal reports from the manufacturers or users. These anecdotal reports are essentially endorsements and should be viewed with the same critical eye as any endorsement.

If the TADD is to be successful at incapacitating targets, it will be necessary to 1) determine if the TADD is effective in disrupting the goal directed behavior of an animal surrogate, 2) determine the mechanism of action of the TADD, 3) optimize the TADD output to maximize effect, while minimizing the risk of morbidity/mortality, 4) determine target human effects in the laboratory, 5) determine possible risks from continued shock (at the proposed time of up to 10 minutes), and 6) determine effects from cross-the-heart shocks.

If the TADD is going to be based on TASERTRON's products, then it is unclear as to whether the TADD will be effective against its targets, given that Taser technology weapons are only 80% effective. Furthermore, given that the TADD is only a concept, it is also unclear as to whether the TADD will incorporate the newer Taser technology as well.

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